Solar Coordinates

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Solar Coordinates

- Describe solar position in terms of latitude and longitude
- The position of a point projected onto the plane of the sky can be computed using coordinate transformations
- Solar ephemeris at:

  `http://ssd.jpl.nasa.gov/horizons.cgi`

  Gives heliocentric latitude (`Obs sub-lng & sub-lat`) and PA of spin axis (`N. Pole Pos. Ang & Dis`)

  See example on next slide

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*******************************************************************************
Ephemeris / WWW_USER Mon Mar 26 10:55:44 2012 Pasadena, USA      / Horizons
*******************************************************************************
Target body name: Sun (10)                          {source: DE405}
Center body name: Earth (399)                       {source: DE405}
Center-site name: Toronto
*******************************************************************************
Start time      : A.D. 2012-Mar-05 00:00:00.0000 UT
Stop  time      : A.D. 2012-Mar-06 00:00:00.0000 UT
Step-size       : 60 minutes
*******************************************************************************
Target pole/equ : IAU_SUN                           {East-longitude +}
Target radii    : 696000.0 x 696000.0 x 696000.0 k{Equator, meridian, pole}
Center geodetic : 280.601700,43.6667762,0.1257286 {E-lon(deg),Lat(deg),Alt(km)}
Center cylindric: 280.601700,4621.21286,4381.4673 {E-lon(deg),Dxy(km),Dz(km)}
Center pole/equ : High-precision EOP model          {East-longitude +}
Center radii    : 6378.1 x 6378.1 x 6356.8 km       {Equator, meridian, pole}
Target primary  : Sun                               {source: DE405+DE406}
Interfering body: MOON (Req= 1737.400) km           {source: DE405}
Deflecting body : Sun, EARTH                        {source: DE405}
Deflecting GMs  : 1.3271E+11, 3.9860E+05 km^3/s^2
Atmos refraction: NO (AIRLESS)
RA format       : HMS
Time format     : CAL
EOP file        : eop.120323.p120614
EOP coverage    : DATA-BASED 1962-JAN-20 TO 2012-MAR-23. PREDICTS-> 2012-JUN-13
Units conversion: 1 AU= 149597870.691 km, c= 299792.458 km/s, 1 day= 86400.0 s
Table cut-offs 1: Elevation (-90.0deg=NO ),Airmass (>38.000=NO), Daylight (NO )
Table cut-offs 2: Solar Elongation (  0.0,180.0=NO )
*******************************************************************************************************
 Date__(UT)__HR:MN     R.A._(ICRF/J2000.0)_DEC Azi_(a-appr)_Elev Ob-lon Ob-lat   NP.ang   NP.dist
*******************************************************************************************************
$$SOE
 2012-Mar-05 12:00 *   23 05 19.00 -05 51 10.0  99.5361   1.5737 348.35  -7.25 337.3264   -959.69
 2012-Mar-05 13:00 *   23 05 28.25 -05 50 12.1 110.2484  12.0608 347.80  -7.25 337.3172   -959.69
 2012-Mar-05 14:00 *   23 05 37.48 -05 49 14.2 122.0867  21.8063 347.25  -7.25 337.3081   -959.68
 2012-Mar-05 15:00 *   23 05 46.68 -05 48 16.3 135.8045  30.2620 346.70  -7.25 337.2990   -959.68
 2012-Mar-05 16:00 *   23 05 55.86 -05 47 18.3 151.9959  36.6828 346.15  -7.25 337.2899   -959.67
 2012-Mar-05 17:00 *   23 06 05.03 -05 46 20.3 170.5592  40.1956 345.60  -7.25 337.2808   -959.66
 2012-Mar-05 18:00 *   23 06 14.19 -05 45 22.2 190.1354  40.1457 345.05  -7.25 337.2718   -959.65
 2012-Mar-05 19:00 *   23 06 23.36 -05 44 24.1 208.6480  36.5445 344.50  -7.25 337.2627   -959.64
 2012-Mar-05 20:00 *   23 06 32.54 -05 43 25.9 224.7734  30.0600 343.95  -7.25 337.2537   -959.63
 2012-Mar-05 21:00 *m  23 06 41.74 -05 42 27.7 238.4394  21.5660 343.40  -7.25 337.2447   -959.61
 2012-Mar-05 22:00 *m  23 06 50.96 -05 41 29.4 250.2508  11.8028 342.86  -7.25 337.2356   -959.59
 2012-Mar-05 23:00 *m  23 07 00.20 -05 40 31.1 260.9628   1.3150 342.31  -7.25 337.2266   -959.58
$$EOE
```

Solar Orientation

Ob-lon Ob-lat =

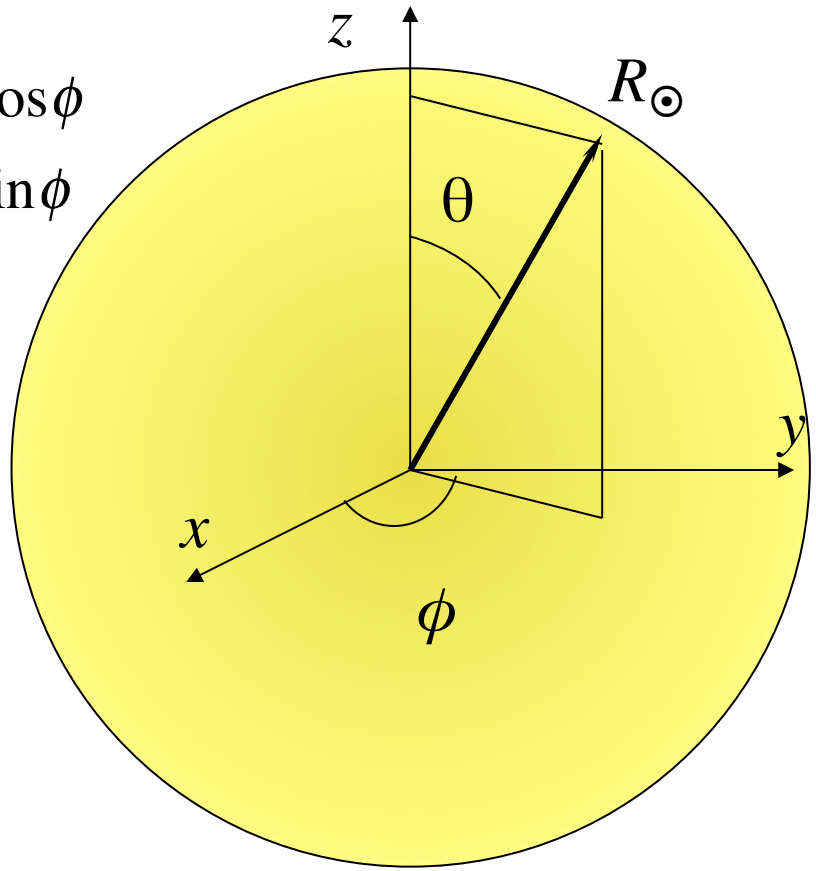
Apparent planetographic ("geodetic") **longitude and latitude (IAU2006 model) of the center of the target disk seen by the observer at print-time**. Light travel-time from target to observer is taken into account. Latitude is the angle between the equatorial plane and the line perpendicular to the reference ellipsoid of the body (e.g., reflects body oblateness). Positive longitude is to the east. For the gas giants Jupiter, Saturn, Uranus and Neptune, IAU2006 longitude is based on the "System III" prime meridian rotation angle of the magnetic field. By contrast, pole direction (thus latitude) is relative to the body dynamical equator. There can be an offset between the magnetic pole and the dynamical pole of rotation. Units: DEGREES

NP.ang NP.ds =

Target's North **pole position angle** (CCW, or east, with respect to direction of true-of-date Celestial North Pole) and its' angular distance from the sub-observer point (center of disk) at observation time. Negative distance indicates the planet's North pole is on the hidden hemisphere. Units: DEGREES and ARCSECONDS

Solar Coordinates

$$x = R_\odot \sin\theta\cos\phi$$
$$y = R_\odot \sin\theta\sin\phi$$
$$z = R_\odot \cos\theta$$



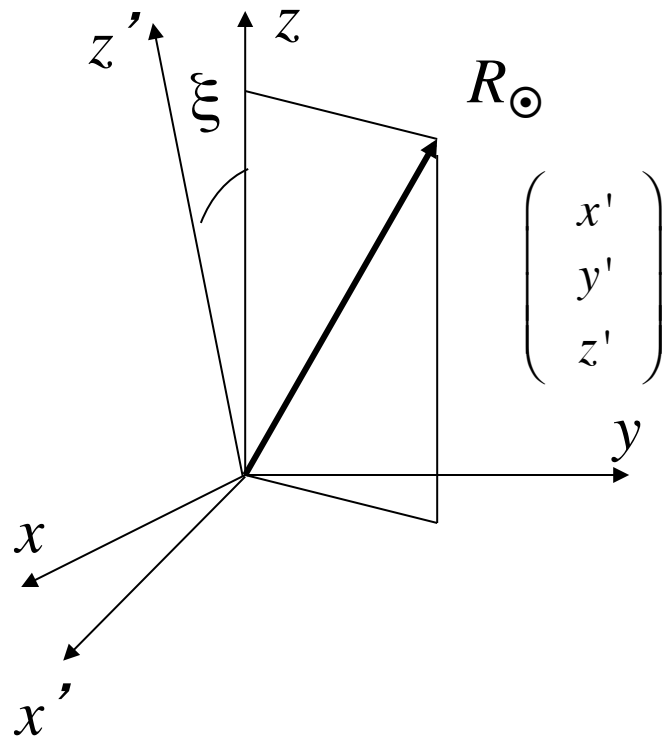
$$\dot{x} = -R_\odot \sin\theta\sin\phi\dot{\phi}$$
$$\dot{y} = R_\odot \sin\theta\cos\phi\dot{\phi}$$
$$\dot{z} = 0$$
$$\dot{\phi} = 2\pi / T$$

T = rotation period

The z-axis is the solar spin axis

Coordinate Transformation #1

The solar spin axis is not perpendicular to the ecliptic—the center of the sun as viewed from earth is not *b=0*

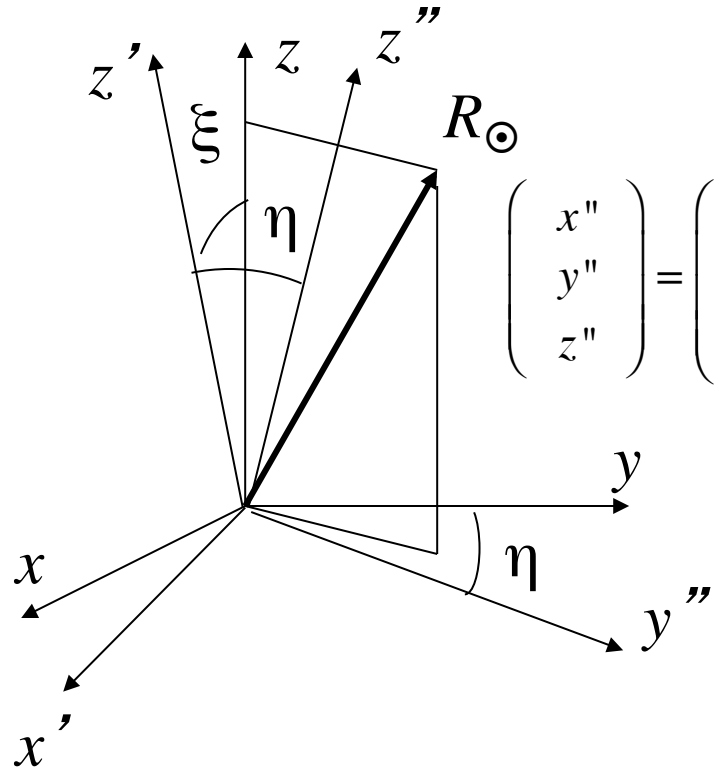


$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = \begin{pmatrix} \cos\xi & 0 & \sin\xi \\ 0 & 1 & 0 \\ -\sin\xi & 0 & \cos\xi \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

Rotate about the *y*-axis by the angle ξ
Tilt of the solar spin axis towards the earth

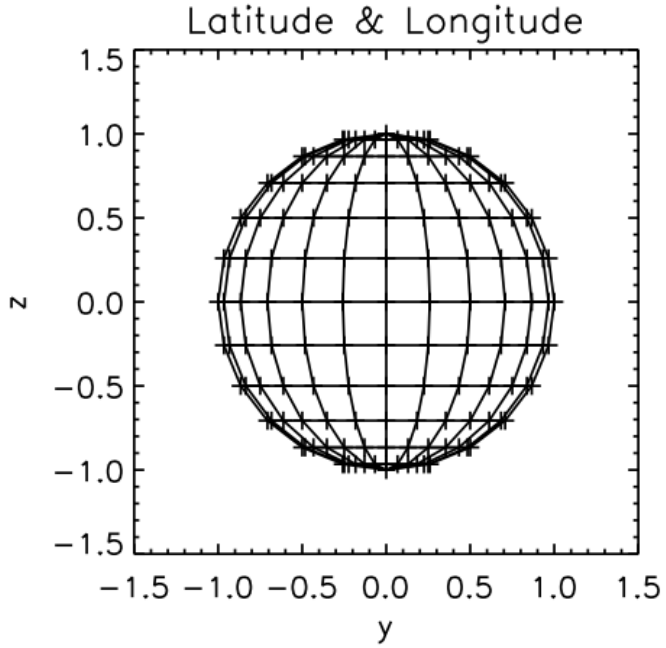
Coordinate Transformation #2

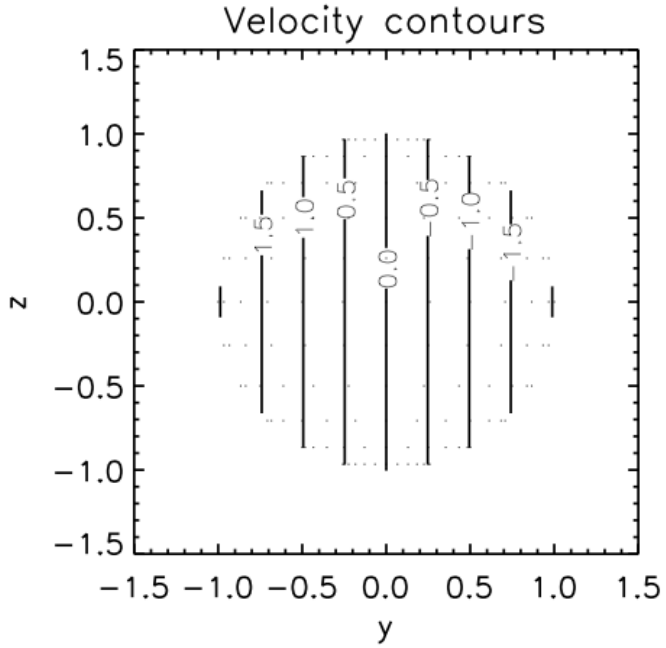
The projected solar spin axis is not oriented N/S

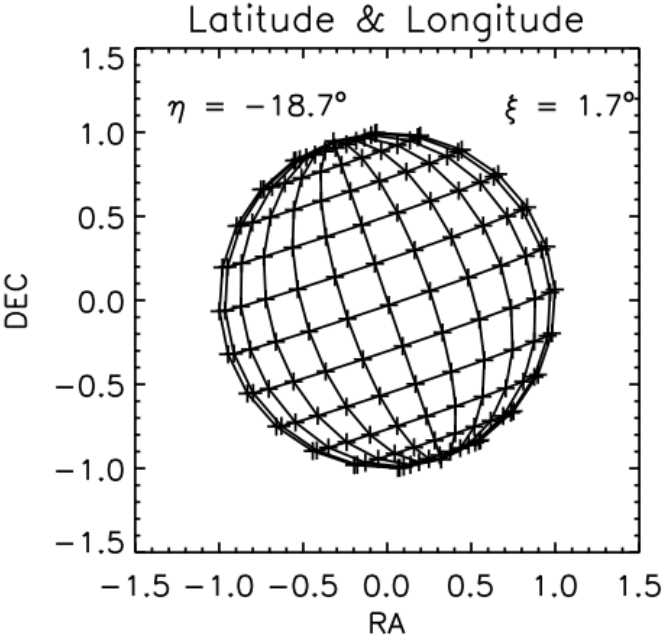


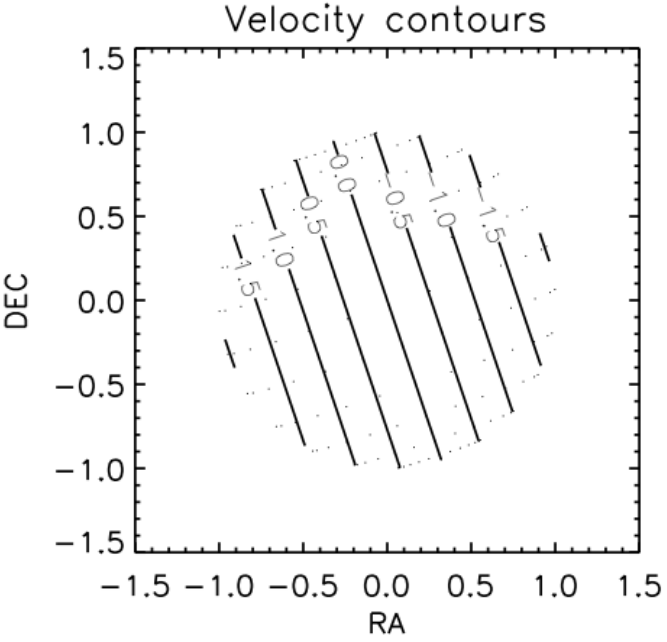
$$\begin{pmatrix} x'' \\ y'' \\ z'' \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\eta & \sin\eta \\ 0 & -\sin\eta & \cos\eta \end{pmatrix} \begin{pmatrix} x' \\ y' \\ z' \end{pmatrix}$$

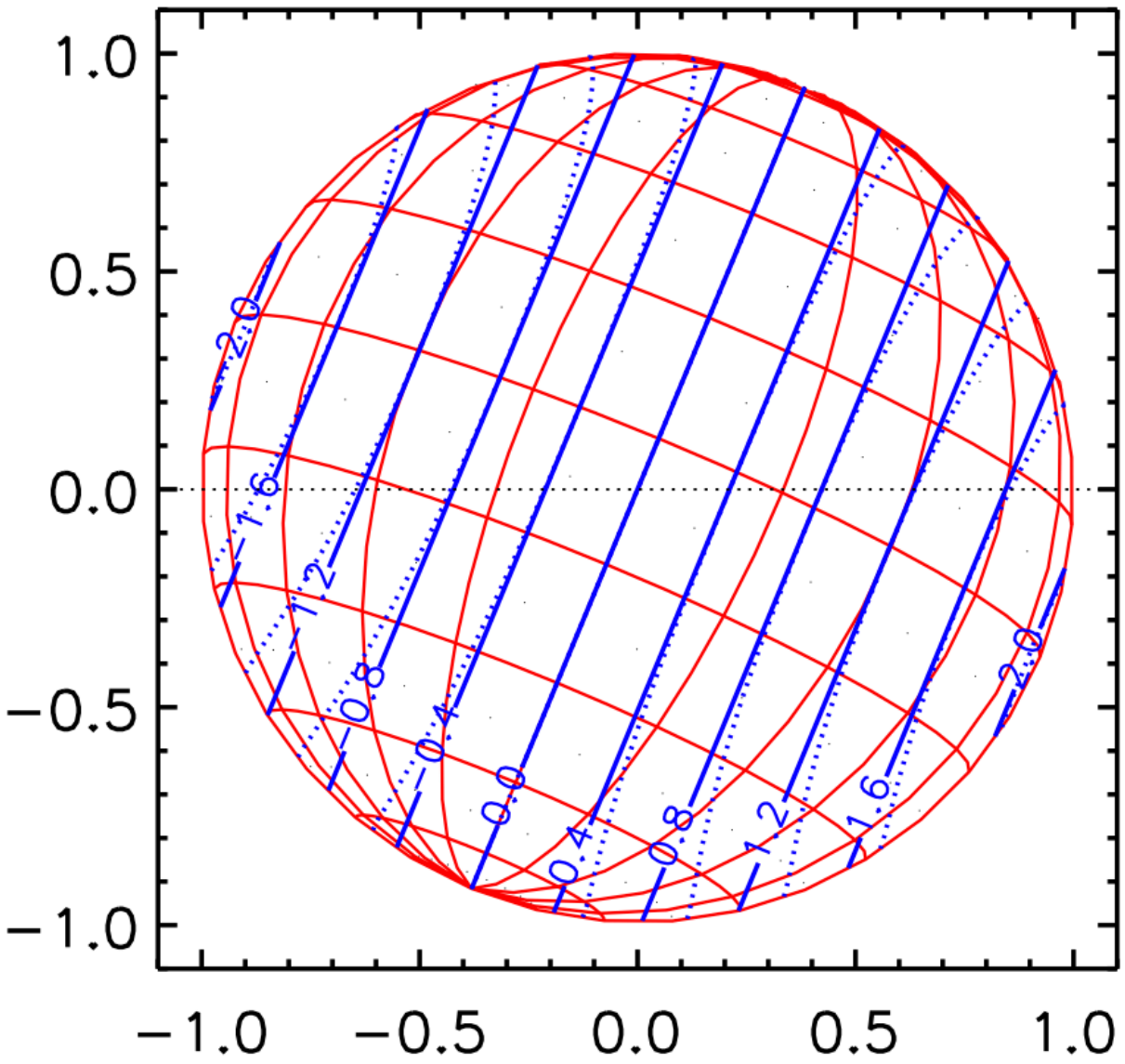
Rotate about the x'-axis by angle η
Orientation of the spin axis relative to north


Latitude & Longitude
z
y
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5


Velocity contours
z
y
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5


Latitude & Longitude
η = −18.7°
ξ = 1.7°
DEC
RA
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5


Velocity contours
DEC
RA
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5



$\xi = -7.25°$
$\eta = 337°$